A THIRD FACTOR IN THE VARIATION OF PRODUCTIVITY: THE LOAD FACTOR

I. The place of the load-factor concept in economics.

The load factor, as defined by electrical engineers, is the ratio of average to maximum load for some specified period. More generally expressed, it is the ratio for a particular good or service of the average demand (in the sense of "demand" as used in economics) through a period of time to the greatest demand at any one time within the period. This concept, as it applies in relation to the commercial supply of electric energy, will be dealt with more in detail below.

It is the purpose of this article to discuss not the load factor as such but rather the extent to which a consideration of the principles involved may disclose ideas that are of general applicability in economics. We owe the term to the electrical engineers. But it is not impossible that economists will prove the better interpreters of an idea that relates so definitely to economic technology.

The load-factor concept relates to a very important subject in economics—to no less a subject than the variation of the productivity of material agents. First in respect of both date of discovery and of fundamental importance among the principles governing the variation of productivity is "diminishing returns." Second is the economy of large-scale production, often none too aptly referred to as a principle of "increasing returns." We are not here concerned with the limitations under which these principles operate, but it should be noted that the second is of less general significance than the first. The "load factor" refers to a third important phase of the variation of productivity, distinct from each of the others, though perhaps not so general in scope. In brief, cost per unit of product varies according to : (1) the difficulty of obtaining the services of relatively scarce agents of production; (2) the magnitude of the commercially practicable scale of production; and (3) the degree to which the conditions of economic demand, apart from maladjustment of the supply of productive capacity, permit the full utilization of such capacity. It is with the third phase of the variation of productivity and cost that this article deals.

The terms ordinarily employed to designate the first two of these factors are open to objection, being insufficiently definite in

meaning and not lending themselves to generalization. "Diminishing returns" and "increasing returns" are not actually, as the words suggest, the opposites of each other, for in the one case the reference is to a given area of land (or quantity of other productive agent) and in the other to the unit of business enterprise. Farms, as cultivated more or less intensively, may at the same time exhibit both diminishing returns and increasing returns; that is, the return per laborer or per $1000 of capital employed upon the land may be relatively smaller on the more intensively cultivated farms than on those under less intensive cultivation, but managers may find more scope for organization and directive ability in the former case so that their net returns are greater than in the latter case. The combined return will exhibit the more or less balanced result of the action of both factors. The commercial value of services and products has no necessary connection with the phenomena in question, though it happens to be convenient to measure quantity of capital in terms of dollars.[1]

The applicability of the principle of diminishing returns, moreover, has been restricted to agricultural land by the classical economists in ways that are of practical significance as well as of great historic interest. Such restrictions, even if not entirely logical, inevitably make the term less suitable for the general concept.

I have therefore sought other names for the two familiar factors in the variation of productivity, and will in general refer to the first as the *proportionality*[2] *factor;* to the second as the *density factor.* A third, of course, is the *load factor.* There is an evident advantage in having the form of all three terms thus parallel.

[1] Commons, for instance, in his *Distribution of Wealth* (1893), pp. 158-159, is inclined to extend the principle of diminishing returns to the highest degree of generality by measuring return in pecuniary instead of physical units. This in effect confounds diminishing returns with diminishing utility and deprives the former of its distinctive content. See also the following footnote.

[2] *Cf.* Carver, *Distribution of Wealth* (1904), p. 65, where "proportions" is used in this way. Wicksteed, *Common Sense of Political Economy* (1910), bk. II, ch. 5, acutely criticises the older ideas of increasing and diminishing returns and gives some effective illustrations of the latter as a matter of proportionality. But his statement that the latter is a "sterile proposition" is ill-considered, and he is too ready to accept pecuniary measures of the quantities whose variation is in question as sufficient. Davenport, in *Economics of Enterprise* (1913), ch. 23, discusses the "law of proportions" as a technological as well as a pecuniary matter, though he overemphasizes interpretation in terms of price.

The development of the idea of diminishing returns, as resulting from relative scarcity of land, into a general principle exemplified wherever there is deficiency in the supply of any of the means of production, or lack of proportion between complementary agents, has come about quite recently. If we may call the more general conception the proportionality factor, "diminishing returns" properly retains its time-honored reference to land, though hardly to merely agricultural uses of land. Its phenomena are, of course, only a species of the effects of the proportionality factor. But the most important species may well have its distinctive name.

The concepts here dealt with all relate to economic technology and therefore the terms used should not suggest a different sort of thing. It might seem appropriate to call the second the concentration factor, but for the fact that this could easily be taken to refer to the financial control and direction of industry rather than to technological aspects. It is true that the large-scale manufacturing plant requires the concentration in one spot of the means of supplying a large area or an extensive market. The tendency is not ordinarily apprehended as causing density in the geographical distribution of the processes of manufacture, but, once pointed out, the fact is evident. "Concentration," moreover, does not suggest what happens when the development in population and industry of a railroad's territory gives it more traffic and larger profits. Hence "density factor" seems to be the term most generally applicable and least likely to be misunderstood in referring to the second principle. "Large-scale production" in its narrower sense is not intrinsically objectionable—though density rather than volume of transactions is what is really important—but the phrase has not the desired parallelism with its congeners and it also has been applied to describe "combination" or concentration of control, which is a different matter and an affair of commercial policy rather than of economic technology.[3]

In one important particular the scale factor is different from what we may call the density factor in the narrower sense. The scale on which an ordinary manufacturing plant is constructed can be voluntarily determined with reference to the existing or immediately prospective degree of condensation of demand or to

[3] Bullock's term for the effects of the density factor is "the law of economy in organization" ("The Variation of Productive Forces," *Quarterly Journal of Economics*, vol. XVI, 1901-1902, p. 472).

the "extent of the market." In the case of services rendered in a particular locality, on the other hand, the capacity of the plant will most likely be determined chiefly by technological considerations, and its full utilization will wait upon the growth of demand, which in turn is dependent chiefly upon growth of population. Therefore the density adjustment is in this case largely passive. When there is a material product susceptible of transportation, furthermore, the process of condensing the demand from larger and larger areas facilitates the deliberate exploitation of density-factor economies in a way that is not open to the "service" industries. But a distinction between the density factor and the scale factor along this line would be chiefly a matter of emphasis. They are, at any rate, species of the same genus, or varieties of the same species.

Whether it is desirable to make a distinction between the density factor and the scale factor is important in this connection only in relation to the use of the former term in the more general sense. Mass is the product of density times volume, density being a ratio. But "place" must be taken in a liberal sense in economics, according to which sense scale (or mass) and density become practically synonymous. With reference to the density factor, condensation relates not to a given area, still less to a given number of cubic feet, but to a "place" that may include any convenient number of contiguous or associated acres, the limits of the place being determined merely by the possible extent of one management.

The relation between the three factors is summarized in the following tabular statement:

Designation of principle	Condition to which it relates	How dealt with practically
Proportionality factor Diminishing returns	Degree to which relative quantities of various economic agents used in conjunction with one another are strained, especially with reference to the crowding of specific quantities of the most costly ones.	Tendency to increase in unit cost held in check or reduced by substitutes and by straining the proportion in which agents are best combined.

Density factor Extent of the market Increasing returns Large-scale production Economy of organization	Degree to which the quantity of the product demanded at a given place admits of or promotes the most economical organization and scale of operations.	The advantages of lower unit cost are gained by transporting the product greater distances or they develop automatically with increasing density of population or increasing general purchasing power. Price differentiation is to some extent used to promote sales.
Load factor	Degree to which conditions of demand and the cost of keeping products permit continuous operation of plant and of individual machines, etc.	Invention and application of means of storage. Diversity of uses develops along with density to a considerable extent automatically, but especially price-differentiation is deliberately employed to smooth out and promote the continuity of demand. Educating the consumer to greater regularity in purchasing counts for something.

II. The load factor in relation to the supply of electric energy.

The term "load factor" was invented and its use has developed in connection with electrical supply. The load factor is always, either explicitly or by implication, a determining consideration in electrical rate making. The term has been rather loosely used. The authoritative definition of the Standards Committee of the American Institute of Electrical Engineers adopted by the Institute is: "The load factor of a machine, plant, or system is the ratio of the average power to the maximum power during a certain period of time." It should be noted that the reference is to economic determinants, that is, to conditions governing the variation of demand, without more relation to generating capacity than is involved in the assumption that it is sufficient to meet the maximum requirement.

The connection between the load factor of a central station and the kilowatt-hour burden of the charge for fixed capital is evident. The load-factor ratio may be stated as a ratio (per cent) or as a certain number of hours' use of the maximum demand. In something like this latter form, that is, as average hours' use per day of connected installation, it is frequently explicit in electrical rate schedules. But the consumer's connected load, or some

defined fraction of it, is usually, in this application, the makeshift representative of the second term of the load-factor ratio. It is obvious that a company with consumers using twice as many kilowatt hours as the consumers of another company having the same system maximum will require but half the generating capacity of the latter per kilowatt hour distributed and will thus be free from a heavy burden of fixed charges, to mention only one element in the consequent saving.

To illustrate the range of variation of the load during 24 hours, we may cite figures for the New York Edison system in Manhattan and The Bronx. Because of the density and diversity of the consumption of electricity in this territory, the range of variation is less than for but few favorably situated companies. The data of hourly output for clock hours as averaged for four December, 1913, work days excluding Saturday, this being the period of heaviest demand, show a maximum hourly output of 183 per cent of the average and a minimum of 34 per cent, the range of variation being thus 149 points per cent. The diurnal load factor of nearly 55 per cent (100/183) is, of course, exceptionally good. The annual load factor of the system in 1913 was about 34 per cent.[4]

It is for the best interest of an electrical company so to adjust its rates that consumers at off-peak times—that is at times when the load is light or at any rate less than the maximum—will obtain some benefit from the comparatively low cost per kilowatt hour of energy supplied to them. If one consumer uses electricity for a single hour a day and another for five hours, and if their kilowatt demand or utilized connected load is the same, the burden to the company on account of the fixed investment is five times as great per kilowatt hour for the first as for the second consumer.

The above paragraph contains a hint of a necessary qualification. If the 5-hour consumer takes his current steadily from 12 noon to 5 p. m. and the 1-hour consumer from 5 to 6 p. m., the company is benefited rather than otherwise by the nature of the demand of the short-hour user. If the needs of the long-hour consumer were of decisive importance in causing the investment to be made, then the sixth-hour consumer, causing no additional investment, might be said not to impose any additional cost on ac-

[4] Vol. III of the *Annual Report of the New York Public Service Commission of the First District for 1913,* p. 54. The data for the preceding comparisons are shown on pp. 60-61 and, in more available shape, in Diagram II.

count of capital charges. The load factor of an individual consumer does not sufficiently determine the fixed cost he imposes unless his maximum load or the peak of his demand comes at the same time as does the system peak.

The diversity factor takes account of the difference in time between the peak of the demand of a consumer or class of consumers and that of the central station. It is defined by the Standards Committee of the American Institute of Electrical Engineers as "the ratio of the sum of the maximum demands of the subdivisions of any system or part of the system to the maximum demand of the whole system or part of the system under consideration, measured at the point of supply" (that is, at the common point). The importance of diversity to the theory of rates is evident from the illustration above given.

It is, of course, the peculiar nature of the commercial supply of electric energy that has led to the development and use of load-factor concepts here rather than elsewhere. The fundamental peculiarity is the economic impossibility of providing electric energy ahead of demand and storing it at will until the consumer wishes to use it. Most goods can be stored, though at more or less cost. Electric energy for ordinary use can not be economically stored to any considerable extent. Hence the problem of the electrical enterprise is so to develop and train economic demand that it will largely adjust itself to the conditions of supply instead of, by its arbitrariness, increase costs in a way that must ultimately react to the disadvantage of the consumer. The unit cost of interest and depreciation is not correctly calculated when simply prorated over the kilowatt hours taken.

Another element in the situation which favors the development of load-factor concepts in the electrical industry rather than elsewhere is the very large portion of total unit-cost that is made up of carrying charges for fixed investment, that is, of interest and depreciation. In respect of the dominant importance of capital (in the large sense, including land) as compared with labor employed, railroads probably rank higher than any important branch of manufactures. But this ratio is almost as large in the electrical industry as it is for railroads. For hydro-electric plants it is doubtless often much larger.

The central-station electrical industry, furthermore, is conspicuous for a very high rate of depreciation, especially so if this

term is used to cover obsolescence. Hence fixed costs per unit of product, which can not be neglected with impunity in any industry, are of greater importance in the electrical branch than anywhere else.

Why, it might be asked, have load-factor concepts developed in connection with the electrical industry rather than with the railroads? In both cases we find highly developed systems of differential rates that seek to distribute the burden of fixed charges unevenly in a way the public is prone to think unjust. The dominant importance of fixed capital is the fundamental factor in both cases. But the policies at the foundation of the classification of freight can not be reduced to quasi-mathematical rules. The elasticity of the demand for carriage is not an engineering but an economic fact. There is no difference in physical cost for the carriage of different kinds of freight of given weight and bulk for equal distances. Differential rates have been developed in order the more fully to utilize the railroad plant. But the policy has little reference to time, and is certainly not primarily intended to provide work at slack times. The time adjustment may, if necessary, be effected by delay in transmission. The economic nature of the problem appears to be generically the same for the railroad and for the electrical company in the sense that both are striving fully to utilize an existing plant, but in the one case the time of demand is of little importance while in the other it is all-important. Of course the elasticity of the demand of a particular class of users of electric current will not fail to be considered by an electrical company in determining to whom low rates shall be offered, but this element of the situation is generally quite overshadowed by regard for load and diversity factors.

In order to improve its load factor, an electrical company will offer low rates for uses that normally require off-peak service, especially if such uses are new and developing. Beginning with street lighting, the electrical-supply business has gradually extended to commercial lighting, domestic lighting, industrial and other motor or power uses (such as elevator service), storage battery service for automobiles, various domestic appliances, and, finally, refrigeration. The last-mentioned is perhaps the prospective field of large importance next to be occupied. Electric heating on a sound economical basis seems to be a thing of the more remote future. Most of the applications mentioned, especial-

ly the later ones, have been favored with special attention and low rates by electrical companies.

An economic interest in load factors need not take us further into details. It is the purpose of this paper to deal with the generalizability of such concepts, not with their application to a particular industry or community.

It is worth while to mention in this connection the "capacity factor." This may be defined as the ratio of the average output of a given period, usually a year, to the theoretical potential output, supposing continuous use of rated capacity. This is not of peculiar importance to the electrical industry. Nor is it of theoretical interest for the study of load factors. The idea, however, serves to correct a possible mistaken inference from these ratios as ordinarily computed. No electrical plant could run at full capacity for every hour in the year. When there is no available reserve capacity, the realized capacity factor is the same as the load factor. The greatest physically practicable capacity factor marks the limit of possible utilization—supposing load and diversity factors so ideal that operation can be continuous so far as thus controlled by economic conditions—under existing conditions of engineering technique. The capacity factor has often been confused with the load factor. Sometimes capacity factors may be used to advantage for statistical purposes where load factors can not be ascertained.

III. Public services other than electrical supply.

The applicability of the load-factor concept to a given enterprise or kind of business depends upon two conditions.

First, there must be heavy investment in fixed capital. It is unnecessary to prove or illustrate the fact that modern industry is highly "capitalistic," in this sense of a word used also in other senses, and that it tends to become rapidly more so.

The second requirement is that the product be of such a nature that the time and the place of use can not be varied at will to suit the notions of the consumer. Any adjustment there may be must be made in advance, and if the consumer does not conform his choices to expectations, the product or service offered fails of its economic purpose. It must be used "on the spot" or immediately where and when it is made available for consumption. "Where" and "when" are, of course, to be taken in an economic and elastic, rather than a metaphysical, sense.

The enterprises of any industry that meet these two conditions have load factors, and their unit costs vary according to whether the load factor is good or bad.

In a general way it is the "public service" enterprises which fulfill the above requirements in the highest degree. The word "service" here may be taken to have substantially its usual economic sense. It is especially because the consumer can not exercise an effective option as to where and when and by whom he shall be served that such enterprises are always more or less monopolistic. The central-station electrical industry, from which the term load factor comes, is one such. All transportation agencies—steam railroads, street railroads, the merchant marine—belong in this class. The service of merchant ships is peculiar in so far as the supply may be adjusted to the variations of demand throughout all portions of the globe that are accessible to water transportation. In this case the "when" of the service is most important and the "where" rather incidental. Gas and (urban) water supply—though in these cases material commodities are placed in the hands of the consumer instead of the supply being strictly a service—constitute another class of public service enterprises. They are peculiar in that the gas and water may be stored. There is thus some emancipation from the time restriction on consumption. The telephone and telegraph are definitely and unqualifiedly of the "service" class.

It is often assumed that there is something about the political nature of public service corporations that constitutes them a class by themselves. But the fundamental reasons why they are quasi-public or "affected with a public interest" are economic. Their monopolistic power (which, however, does not hold of the merchant marine) is due to the large amount of fixed capital they require and to the impossibility of making the services of a particular enterprise available except in its own restricted area. Hence the need of public control to take the place, in part, of competition as a regulator of prices and of the quality of service. The fact, also, that the consumer, especially the small consumer, has practically no choice, but must be served by the one corporation or go without, makes him unable to protect himself against discrimination and unfair treatment.

On the side of the company, the density factor and the load factor give the railroad or other public service corporation special incentives to differentiate and discriminate in their charges.

Hence it is necessary to regulate the public service corporation with reference to the method as well as to the total amount of its charges.

The supply of water to a city might be expected to be a particularly significant illustration of the way the load factor works, because the commodity apparently costs nothing itself, aside from carrying charges for fixed capital in reservoirs and pipes and similarly invariable expenses. The physical commodity is to be had in unlimited quantity. Pumping, however, is usually required and this is a variable cost. But it is a small factor. A city's water works are generally owned by the municipality. Therefore the prices charged may or may not conform to load-factor principles or to any other principles, because the amount collected may be, as it is often called, a "tax" rather than a price. The problem of adjusting rate of supply to rate of demand in this case is seasonal and due not so much to the variation of demand as to that of supply. There is likely to be tremendous expenditure for storage accompanied by little or no attempt to regulate demand, not even to the extent of preventing waste. But the reserve supply has also largely an insurance function. And no adjustment of water rates should restrict the use of water for sanitary purposes.

The peculiarity of the relation of the water supply to demand will become more important as water comes to be extensively impounded to be used for power. In connection with long distance transmission by electricity, such a development suggests hydro-electric plants on a great scale. For such plants it is recognized that the load factor is even more important than in central-station service.

In telegraphic service the night-letter (off-peak) business at specially low rates is an interesting application of load-factor considerations. Off-peak ocean cable rates are also being tried. These policies are adopted with the express purpose of lowering cost by improving the load factor. Emphasis upon such matters, if not attention to them, is a matter of recent years.

The telephone has been recognized as peculiar among public service enterprises, because the density factor that increases the proportion of profits as business increases does not seem to operate here as certainly as in other cases. But this is owing to the rather unessential circumstance that the subscriber was originally taken as the unit of service instead of the call. The present tendency is towards measured in place of unlimited service, at least in large

cities, where the rate per subscriber is in effect merely a guaranteed return. The pressure of the daily telephone peak in cities is of great importance, since an overload can be taken care of only by developing human capacity, or by delay. Commercial methods of depressing the peak have not been developed.

The relation of the load factor to the steam railroad rate schedule is rather incidental than of fundamental importance because the density factor is here of more decisive influence than the other. Carrying charges for fixed capital which it is desired to utilize more fully are still the controlling element in the situation. The result of both factors is differential rates, but of two different types. In steam railroad practice the principal aim is to increase business and the dominant consideration is regard for what the traffic will or will not bear. An electrical enterprise is also interested in increasing the load but is, or should be, much more interested in equalizing it. A railroad may double its freight without any appreciable addition to its investment except for rolling stock, and the required increase for that, owing to the opportunities of the back haul and of partly filled cars, may be much less than 100 per cent. An electrical company must double its generator capacity to provide for such additional demand, unless it improves its load factor. Its investment for transmission and distribution is less likely to be much affected, thus resembling the track and roadway of a railroad.

But the load factor does somewhat affect the rate policy of railroads. Excursion rates at particular seasons are explicable by reference to it. Differences in respect of the load factor also are doubtless one reason for a higher charge for passenger service than for non-perishable freight. The seasonal variation of the amount of traffic[5] is one consideration in freight classification, but this is no doubt governed in the main by regard for the density factor. The economy of fully loaded cars and of longer freight trains, which has been much emphasized of late, is an affair of the load factor. The diurnal variation of one sort of passenger demand is important for steam roads terminating in large urban centers with considerable commuting population. Passenger stations may have to be specially adapted to the volume and character of commuter traffic.

[5] *Cf.* Ripley, *Railroads; Rates and Regulation*, p. 100, for an illustration of the importance of this factor as indicated by the variation of gross and net revenues from month to month.

In street railway service there are some peculiarities from which the usual 5-cent flat rate may distract attention. The problem of the daily traffic peaks or "rush hours" is familiar.[6] The overloading of street cars to meet the peak is less restrained by physical conditions than in the case of electrical machines. While the careless overloading of a generator harms the property of the corporation, the rush-hour street railway overload merely causes discomfort to the passengers. Hence the perennial plaint of the strap-hanger. In fact, the street railway can not economically give the same grade of service at the rush hour as at other times. The attempt to do so would greatly increase unit costs for such passengers. The street railway has to do also with some specifically electrical peak problems, but they are comparatively unimportant and of engineering more than of economic interest.

Investors are sometimes misled by observing the conspicuous density of traffic under peak conditions into providing large amounts of capital with regard to such conditions rather than with regard to average demand. The great seasonal demand for transportation from New York to Coney Island, for example, doubtless caused the too rapid supplying of facilities for this traffic some thirty years ago.

Any measure that will effect a smoothing of the transit load has great economic advantages. Whether hours of employment of different sorts of labor could be adjusted with reference to this situation is an interesting question. The facetious classification of morning commuter traffic as consisting successively of "works, clerks, and shirks" has an element of interest in this connection. The adjustment of railway rates with a view to effecting a reduc-

[6] It is of interest to note that John Hopkinson—to whom more than to any other individual the appreciation by electrical men of the importance of the load factor is due—in his pioneer discussion, uses a railway illustration to make clear his meaning, as follows: "For example, the Metropolitan District Railway must be prepared to bring in its thousands of passengers to the City at the beginning of the day and to take them back in the evening, and for the rest of the day it must be content to be comparatively idle. In this case the services cannot be stored. The line must be of a carrying capacity equal to the greatest demand, and if this be great for a very short time the total return for the day must be small in comparison with the expense of rendering the service. In such a case it would not be inappropriate to charge more for carrying a person in the busy time than in the slack time, for it really costs more to carry him." See his paper "On the Cost of Electric Supply" in *Original Papers*, vol. I, p. 256.

tion of the peak—daily, weekly, or seasonal—would doubtless encounter a good deal of prejudice, though higher Sunday rates are not unknown.

The collection, transportation, and delivery of mail constitutes a service in which the load factor is of great significance. Here the labor element is a more important consideration than the fixed capital directly involved. But promptness of service is of first importance. Hence the problem of the Christmas peak. One reason for the establishment of the parcels post was doubtless the desire to use more fully an expensive organization, but with reference to the density factor rather than the load factor. Whether the present classification of postal rates, with distance disregarded except for parcel service, is economically sound is perhaps questionable. It is merely a historical product and not well thought out.[7] The extension of the parcels classification to books, however, remedied one conspicuous anomaly.

IV. Other business enterprises.

The principle once grasped, it is seen that the load factor is significant throughout modern industry, though it does not attract attention to itself by a peculiar system of rates or prices except in electrical supply.

There are some industries in which continuous operation throughout the 24 hours of the day and the 7 days of the week is practiced. However, this involves the employment of two or three shifts or sets of laborers and night work, both of which conditions count against such a continuous use of fixed capital. Hence where 24-hour work is the rule, some other consideration than economical use of capital dominates the situation. It is, for example, only an incidental and minor advantage of the running of blast furnaces 24 hours a day that by such continuous use there is some small saving of interest cost. The ordinary manufacturing plant, a cotton factory, for example, resorts to night work only when there is pressure of unusual demand.

In the case of the ordinary factory, the problem of the full utilization of capital is a question of what to do in slack times, especially slack seasons. The retention of a trained labor force through the dull season is often an important consideration. Manufacturing "for stock" is of course the ordinary recourse, but

[7] The report of the Commission on Second Class Mail Matter (transmitted to Congress February 22, 1912) shows this among other things.

the determination of how far this process shall be carried, or of what selling and other devices may be adopted to prevent the accumulation of too large a stock, comes up, and is indeed substantially the same old load-factor problem in its seasonal aspect. If the product of the factory is not a standard article but is subject to the caprice of fashion, it does not pay to manufacture much ahead of actual orders. Thus throughout the field of manufacturing, although continuous utilization through the hours of the day is seldom to be considered, the seasonal load factor is more or less important.

It happens that New Jersey's Bureau of Statistics of Labor and Industries gathers and publishes some statistics indicative of load-factor conditions in various branches of manufacture. The ratios are really capacity factors, but they illustrate the point under discussion. In the 1910 figures, which are the ones at hand, the average figure for all industries was 74.92 per cent and for 25 specified industries 74.00 per cent.[8] The minimum ratio was 64.42 per cent, for structural steel and iron, and the maximum 88.12 per cent, for paper. These figures are doubtless based upon the use of the plant by a single set of workmen, without alternating shifts, and for the usual number of working days in the year, such use being rated 100 per cent.

The Massachusetts Bureau of Statistics publishes similar data for "days in operation."[9] The following is quoted from the report for 1910:

> In 1910, exclusive of Sundays and holidays, there were 305 working days, and all of the important industries reported short time to a greater or less extent for the year. Establishments in the boot and shoe industry, exclusive of cut stock and findings, were operated on an average 283 days; Cotton goods, including cotton small wares, 280 days; Foundry and machine shop products, 296 days; Leather, tanned, curried, and finished, 282 days; Paper and wood pulp, 274 days; and Woolen, worsted, and felt goods, and wool hats, 271 days. Establishments manufacturing Electrical machinery, apparatus, and supplies, were operated 297 days, and Jewelry establishments about 287 days. In some of the smaller industries, such as Malt liquors, Show cases, and Musical instruments and materials, not specified, we find practically continuous employment. On the other hand, in Brick and tile, a seasonal industry, the establishments were operated only about half time, or 153 days on an average. Lumber and timber products shows an average of 247 days.

[8] P. 31 of the annual report for 1911. The ratio is termed the "proportion of business done."

[9] *Twenty-fifth Annual Report on Statistics of Manufactures,* p. xxvii.

Reduced to terms of per cent these figures, in order, are as follows: 92.8, 91.8, 97.0, 92.5, 89.8, 88.9, 97.4, 94.1, 50.2, 81.0. These ratios are, of course, not directly comparable with a central-station load factor.

It has already been intimated that these are strictly a species of capacity factor, rather than load-factor figures, and that the conception of continuous operation underlying them needs to be made explicit. Doubtless a large proportion of manufacturing establishments have some reserve capacity to provide for future growth. The only suggestion the figures themselves contain as to what allowance should be made for this is that possibly the largest average ratio for an industry would fall short of 100 per cent only by the average amount of the reserve in question, and that this reserve ratio would vary only slightly as between the averages of the different industries. But the strict annual load factor would take no account of fluctuations of demand due to "trade cycles" covering several years, though this rather than the seasonal variation may be of most importance in causing an uneven and usually short load for efficient manufacturing plants.

Though not so named, the diversity factor is very commonly of recognized importance in ordinary business, and its importance presupposes the importance of the load factor. One advantage of the department store over the specialty "shop" is that it can shift the disposition of space and clerical force according to the season's needs, thus improving its annual load factor. The profitableness of commercial banking is entirely dependent upon the diversity of the demands of depositors for funds. A reserve of $100,000 will under most circumstances easily meet aggregate possible demands five times as great.

The variation of demand may be weekly, but if this is a matter of a Saturday afternoon and Sunday discontinuation of operations, that is no more thought of than shutting down over night. If the variation is the reverse of this, so that there is a marked Sunday peak, then the effect is likely to be noticed in a stiffening or increase of prices. Reasoning rather short sightedly, the public is likely to think that any such increase in unit prices at the period of largest demand is extortionate. We can not be sure that under these circumstances the commercial motive will not lead to attempting to make too much of the opportunity, but there is also the other side of the matter, namely, the question as to what can be done with the investment and the time of those engaged during

the unprovided for five or six sevenths of the week. Such sixth or seventh-day enterprises, however, are often merely auxiliary occupations and even the undertakings of children. The holiday sale of drinks, fruit, and confections in suburban "park" resorts is the most conspicuous instance of this sort of thing. But this graduates into restaurant and hotel-keeping for similarly variable weekly and seasonal demands.

Not long ago a certain London hotel advertised the quality of its service as being the best obtainable because its good load factor so reduced its average costs. Whether this is as good advertising as it is good economics may be doubted. It certainly is true that the price for a hotel supplying the needs of transients can not be other than high according to a close comparison of the actual with the theoretically possible use of the investment. Hence Swiss mountain hotels and Jersey coast resorts, once thought of merely as places to go in summer, are now trying to develop winter trade and thus to utilize what would otherwise be idle plant. Some nondescript statistics that happen to be at hand for Swiss hotels in 1906 show monthly capacity load factors (beds used to beds available per night) of 76 per cent for August as compared with 14 per cent for December. The Adirondack hotels also are now seeking winter guests. If we may believe the advertisers, "all-the-year-round" resorts are coming to be the usual kind.

In view of the inevitably low degree of utilization possible, what vanity is it that makes the traveler seek luxuries in hotel accommodations that he can not afford at home? Decorations and appliances that will be idle 250 days in the year must require triple or quadruple recompense for the 100 days of use. The American weakness for having "the best of everything," always traveling "first class" and going to the "best hotels," imposes a tax that only a very prosperous people could stand.

It is because of the load factor that one can get a better lunch at a restaurant which is also a saloon than at one which meets the demand for light noonday meals chiefly and for occasional evening dinners or suppers, and whose plant is otherwise unutilized for most of the 24 hours.

Since the variation of the seasons is the fundamental condition of plant growth, one would expect load factors to be especially important in agriculture. In this case it is the "industrial" demand for uses of means of production that varies, not the demand of consumers for final products. Fixed capital used in agriculture

has a poor load factor because the seasons restrict the use of any kind of agricultural machinery to a particular portion of the year. This holds even where one farmer does the reaping and binding for several neighbors. Threshing and hay pressing are less restricted, the former lasting all the autumn, the latter possibly also through the winter. Probably the chief reason why agriculture is carried on to so great an extent with poverty of appliances is because the load factor for capital used is so unfavorable. Farming can not economically be capitalistic, in one sense of the word, to the same degree as the manufacture of cloth, for example. A seeder that is passed around among neighbors and used by some of them at not just the right time is, even then, of use only during the good days of a single month or six weeks in the year.

In certain kinds of demand there is no recurrence of need. Under such circumstances it is impossible to compute a load factor, because that supposes a period of use and a permanent investment. But the economic interest in this case is of the same nature as in the case of a recurrent peak. The price paid for the use of a grand stand to view a parade must be very large in proportion to the investment. Pageants and spectacles are similarly costly. Hotel accommodations for large crowds at expositions and political conventions should not be expected "at regular rates." Monopolistic exploitation of such conjunctures, unfortunately, is much more likely. But, in the case of specially provided accommodations, there should be some allowance of extra return (in case the enterprise is successful) on account of economic risk.

The attempt to get a high price for a brief seasonal or temporary use of capital often leads to angry protests against so taxing the peak. The summer demand for extra ice and for bathing accommodations affords familiar examples. Public opinion may easily expect too much of dealers in hot-weather necessaries. Holiday travel is sometimes similarly taxed. In all these matters the responsible managers of business enterprises occasionally forget that, even if the public is somewhat prejudiced—and dealers are not the best judges on this point—what is bad business policy can not in the long run be good practical economics.

V. Variation in the employment of labor.

The application of the load-factor concept to the utilization of labor force and to the explanation of certain phenomena of wages and employment is suggestive and clarifying.

The distinction between wages and salaries is not ordinarily recognized by economists as corresponding to any significant difference between these two parts of income from labor. In practice the distinction is partly a matter of social standing, and this fact tends to cause some displacement of the division line by making the salaried class more inclusive than its economic ground. The working distinction easiest to apply is that between employees on the monthly and those on the weekly pay-roll basis. But this difference is extraneous. The fundamental difference is the greater permanency of tenure of those who belong, on economic grounds, in the salaried class. This may be evidenced by a contract of employment running for a year or more. For these reasons salaries are regarded as an "overhead" charge, while the wages of "productive" labor are computed as a part of manufacturing cost as much as the amounts paid for materials. Hence wages may be paid by the hour, as materials are bought by the pound. The employer adjusts the hours of wage-work that he employs to the amount of his product that he can sell only less accurately than he does the pounds of raw material that he buys. But his attitude towards his salaried staff is markedly different, at least in degree. The distinction, however, depends on whether employees are regarded as easily replaceable and to be "laid off" when business is slack. With this goes less strict attention to hours of employment of the salaried, at least the high-salaried, class. The salaried employee, in the functional sense, is expected to work after hours as occasion demands and to give his whole energy to the business, if called upon, while, on the other hand, if business is slack he may attend the afternoon's ball game; and at any rate he expects a summer vacation with pay and, to a considerable extent, a continuance of pay during sickness. The underlying idea seems to be that the salaried man fills a position with a definite function and, within his powers, does more or less, as may be necessary in order to perform it, or at any rate has the responsibility, even if much of the detail is attended to by subordinates. But some degree of responsibility and of irreplaceability (loss in the process of replacing) extends farther down into the "ranks" of industry than is ordinarily assumed. From the number and variety of these not altogether consistent grounds of distinction it may easily be seen why the salaried class is not usually recognized as a distinct economic category.

The functions of the salaried class proper are directive, so-called

executive or administrative, technical, supervisory, and clerical. If we could well distinguish the function of responsible decision on matters of policy, that ought to supply a further descriptive adjective. As it is, "directive" must be taken to include this. Merely clerical employees are included in the salaried class, where they do not all belong functionally, for two reasons. It is chiefly by advancement from such work that the responsible positions are filled. They are also next to the more or less responsible officers or officials and reflect somewhat, and correspondingly benefit by, the importance of their immediate superiors. We are not so far away from feudal notions, and human nature has not so changed in a thousand years, but that to be menial to a king or to a "captain of industry" may give higher social rank and pay than does actual leadership on a smaller scale. The hard-handed foreman and supervisor of mechanical work may suffer in rank by reason of his direct association with the fluctuating labor force. In America we tend to pay him according to his economic value rather than his social standing, though there are plenty of people who think a bookkeeper must be worth more than a construction-gang boss. The development of the engineering professions is bettering this condition and giving the men in the mechanical department more recognition; possibly, however, too often by separating them too much from the actual muscular work. The labor, or the tried and experienced skill and knowledge, of officers and technical and supervisory staff is economically distinctive, and is not measured and dealt with piecemeal according to market conditions.

A large corporation does not dispense with its officers and important salaried employees when times are dull. Common laborers are the first to feel the effects of trade depression. The salaried class, in the proper sense, is seldom affected at all, except so far as such conditions afford occasion for economical readjustments, the causes of which are more deep-lying. Thus it happens that the larger part of the salaries paid by a corporation and chargeable to general expenses are fixed rather than variable costs. They will not change much with the volume of business done, hence the keeping of this element of unit costs low requires full and continuous utilization of the services of the salaried employees. If time and talents are not utilized continuously, there is the same sort of loss as with idle fixed capital. It happens, however, that there is one important difference between their services and the services of some kinds of fixed capital. The slackening of current demands upon

their time may give needed opportunity for study and planning for the distant future. But such planning itself is not altogether a discontinuous function and is certainly not optional. The load factor is nearly as important for "general expenses" as it is for "fixed charges" in the narrower sense.

In relation to wage-earners the load-factor point of view is most interesting as applied to explain some of the peculiar conditions of the "seasonal trades" and other occupations not so called but more or less affected by regularly recurring slack times. But the diurnal load factor also is not without significance in this connection.

The diurnal load factor for laborers is not often important because a man must ordinarily be paid for a day's labor whether he is fully occupied continuously or not. Usually subordinate uses for his time may be found, but a disinclination to do work not in the regular line is an obstacle. Waitresses are likely to be put at dishwashing at other than meal times. Men waiters are less amenable to such a use of their time. There are some important classes of occupations in which a great daily variation in demand is directly reflected in the hours of the employees. Motormen and conductors on the street cars are often required to work few hours at a time with long intervals between; and a new man may be given a run of a few hours only and paid accordingly. Usually only those who have been longest in service are given "continuous runs" for their full day's work.

A less important, but interesting, effect of load conditions appears where work has to be done at unseasonable hours, as in the case of evening amusements, the delivery of milk in a large city, etc.

The seasonal variation of demand is, extensively speaking, more important for the laborer than the diurnal variation. But it is also more easily dealt with by shifting work or combining occupations. Of course the seasonal fluctuation may not be reflected back to the labor for reasons that have already been mentioned. Even where there is a direct connection between the variation of demand and the need of labor, actual employment or pay will usually be more nearly regular or steady than is consumption. This is the case, for example, with the generation and distribution of gas and electricity.

It is in the nature of things that the seasonal trades which attract attention because of conspicuously bad conditions as to regularity of employment are those making use of little or no fixed

capital. Wherever there is a heavy fixed investment there is so strong an incentive to steady use of capital that humanitarian motives are not necessary to induce the giving of steady employment. As with the hours of work during the day, so with the season of work, time of work tends to conform to the time of utilization of the machine. If the machine is costly it is worth while to standardize products and manufacture ahead of orders. If there is no machine, then the entrepreneur has little direct interest in putting any check, for example, upon the decisiveness of the "last word" of fashion.

The common association between the seasonal trades and the sweating system is not accidental. The latter is to be described as the poorly paid work of unskilled laborers, especially of women and children, for unduly long hours, especially such work as is done in the home. Sweating is not a "capitalistic" phenomenon, if by that is meant something involving a considerable use of capital per entrepreneur or per laborer employed, but the opposite. This non-capitalistic character is just what favors putting the whole burden of the seasonal fluctuation of demand upon the laborers. As soon as the employer rents or builds and equips a factory he wishes to use his plant continuously and efficiently, hence he wants to keep a tolerably reliable force of employees and must standardize the conditions of employment and wages. Many seasonal trades will cease to be such as they become more capitalistic. There are some, however, such as the canning of perishable fruits, which must remain seasonal.

The load factor of farm machinery has been referred to above. Here we are concerned with the utilization of farm labor. The problem is simpler than in the case of the load factor of machinery because the available labor may be applied to different kinds of work. Indeed, no occupation, not even that of the complete housewife, offers greater variety than farming. In addition to the incidental application of varied mechanical aptitude and of competence to care for animals, the nature of the work required of the cultivator changes with the seasons and is somewhat different for each crop, of which there are usually half a dozen. But with all this variety, the ordinary farmer finds only odd jobs and chores to occupy him almost half the year. Even the repairing of his buildings can not well be done in winter. There was a time when threshing was the staple winter occupation, but that is now completed in a day or two by steam-driven machinery. If the farmer

has a wood-lot, he may save a few dollars that would otherwise be spent for coal, though this is but small resource. The problem is worse for the hired laborer than for the farmer himself, for the latter can put at least a part of each day into doing chores. Most hired men can get good paying work for some eight months at best. Additional harvest hands are wanted for perhaps one month in the year. Some of these can follow the harvest northward, but that may mean only another month or so of such employment. Dairying is the only all-the-year-round occupation for the farm laborer. In all respects this seems to offer the best load factor for a farm and is correspondingly attractive.

The same force that gives importance to the use of considerable capital per laborer in relation to the problem of seasonal trades operates generally to strengthen the position of the laborer in the matter of getting regular employment at good wages. An idle plant, especially during good times, means a greater loss to the employer the greater the amount of fixed capital he uses. To hold out against a strike, therefore, costs him more. In this situation the employer may rely upon a long-term contract with the union, the terms being readjusted, if necessary by arbitration, from time to time; or he may try to nip in the bud any incipient tendency towards unionism and keep as large a supply of ignorant laborers at hand as is possible. In America the latter seems too often to have been the policy of large industrial corporations. The evident interest of the public in the continuous operation of the railroads coupled with the necessity of using American labor for positions involving direct contact with the public has compelled a different solution there.

In the course of time, as the extent of capital uses involved with the employment of labor increases, we may expect not only more interest in regularity of employment for the latter throughout the year but also a tendency more frequently to work men in shifts through the 24 hours, though at present any such tendency is explicable rather by operating costs. Operating under an 8-hour day for about 305 work days in the year means only a 28 per cent load factor, figured on "continuous rating," even supposing there is full and even employment of working time. But such a condition is not thought to be uneconomical. The necessity of artificial lighting should no longer be much of an obstacle to a 24-hour day for fixed capital. There is, of course, a variation in the laborers' demand for work through the hours of the day such that

one would expect night shifts to be paid higher, since they subjectively cost more. The fact that such a difference is not generally observable where night work is done is probably indicative of lack of bargaining power on the part of laborers.

The normal tendency of an industry having a large amount of fixed capital per laborer to give its men in general more regular employment may be inferred from what is said above. Generalizing on this basis one may logically infer that increased "capitalism" means a lessening of unemployment in society generally. A comprehensive study of unemployment statistics from a load-factor viewpoint would be of great scientific value. This inference as to the influence of capitalism is true abstractly considered, but there are other factors entering into the problem, among which may be mentioned the lessening of outside opportunities for the wage-worker and a corresponding reduction in his bargaining power, and also the connection between increasing fixed capital and cyclic changes between prosperity and depression in industrial conditions.

Labor, or the service a man disposes of or offers for hire, is the most perishable of commodities—if it may be called a "commodity." If not made use of when available it is to that extent permanently lost. There may be some adjustment to the conditions of demand through extra effort on occasion, which is compensated later by a greater amount of time for relaxation. But in the main, labor power is used to best advantage when regular. It is no accident that we speak of labor as service and of the functions of certain corporations as public services. In both cases there is offered the use of a permanent plant or a durable organism which, if not taken at the time and perhaps on the spot, is lost and therefore fails to make a contribution to the support or carrying charges of the person or plant. Uses that are easily stored in material goods do not require such continuity of exploitation.

The agitation against long hours and overtime during a short period of seasonal exigency has not always taken due notice of economic limitations imposed by load-factor considerations. Canning perishable fruit, the season lasting only a few weeks, would seem to be a case where extra exertion is justifiable, in the form of not only longer hours for those who do work but also the temporary industrial employment of women and children who should usually be otherwise occupied. But there ought to be an external check upon such things, which, however, should be elastic rather

than rigid, operating like the requirement of a higher rate of pay for overtime work. Though there is need of every caution as to the mental and nervous strain imposed, it is too often forgotten that regularity and monotony of work does not conform to the needs of our nervous organization so well as does high stimulation followed by a due amount of relaxation. Man has a good deal of "overload capacity."[10] Making regular use of such capacity, however, is a very different matter from making emergency use of it. The engineer's factor of safety is used in the latter way. And of course the employer can not be trusted to say when and how much of labor's overload capacity shall be exploited. The commerce of unskilled labor tends to be inhumane. But it is probably not much more so where the seasons control demand for labor than elsewhere.

Auxiliary employment is of so comparatively little economic (or rather commercial) importance in this country that we have no familiar term for it, such as the German *Nebenwerk*. A thrifty housewife may sometimes do dressmaking for hire in her spare time, but most employment upon textiles has gone to the factories. Women and children in the poorer quarters of New York often have "home work," but its purpose appears to be not so much to fill in time not taken up with housework as to save factory rentals. Our children are usually considered properly occupied with their education. Many American women of the middle classes are much of the time without occupation, because their work at home is mainly directive and industry can not use such fragments of time and interest as they have to offer. There evidently results great economic waste. The load factor for the urban American woman of the comfortable classes who is not in a gainful occupation and has no children is, economically speaking, very bad. But the utilization of the spare time, which is most of the time, of such persons would cost so much for organization and instruction that, doubtless, it is not now practicable. Much of it is devoted to "social service"; how effectively, there is no occasion in the present connection to offer an opinion.

[10] William James's "Energies of Men" (In *Memories and Studies*, p. 227) impressively develops this idea, though of course he does not make use of the engineering term nor recognize the qualification that the engineering analogy should suggest.

VI. The load factor in consumption.

Despite a possible inconsistency with the title of this paper (if "production" is to be taken in the narrower sense), certain significant applications of the load-factor concept in the field of economic consumption should be mentioned in passing. The most important relates to the cost of existential utility.

Existential utility is, by definition,[11] not impaired by the enjoyment of the object affording it, so that, in so far as the effect of activities of consumption is concerned, the thing having existential utility may yield such utility through an indefinite period and in amount limited only by the degree of intensiveness of its utilization. In other words, whether it pays to "invest" much or little in a given object of existential utility depends on the prospective load factor. Aesthetic interests and ambitions often mislead in this respect. But those of us who are not rich do not build elaborate summer homes in the mountains to be used only a month or two. In fact, most of us content ourselves with but one abode to call our own, the reason being the load factor.

It is of interest to note that the load factor of some of our most expensive buildings—theatres and churches, especially—is low, while our residence buildings, with very high load factors, are of comparatively cheap construction. This is very largely due to the economy of multiple utility, but it is also partly the effect of unduly concentrated wealth. It is to be noted, also, that the development of the institutional church means a considerable bettering of the load factor on both the buildings and the staff of religious organizations.

One of the most interesting of recent developments in social amelioration is the argument for a "broader use of the school plant." This is an economic rather than a commercial matter, and as such it rests solidly and soundly on load-factor principles. Similar reasoning is largely accountable for the development of university summer schools. Student rooms in a university town, we are reminded, are much reduced in price in the summer. There is also some seasonal variation in the rent paid for rooms in large cities.

The prompt removal of snow from the streets of New York City—this does not refer to what is done in weather favorable to the street-cleaning department—is a desideratum important to

[11] See the writer's *Welfare as an Economic Quantity*, chapter V.

the consumer. It is doubtless worth all it costs. For example, not far short of $2,000,000 was paid for the Borough of Manhattan alone in a period of a month and a half in 1914[12] for what could not have been called a good job from the point of view of the consumer. But how much could the city afford to invest in efficient equipment when it would be used perhaps only half a dozen days in the year? Such a peak demand can be taken care of only by miscellaneous equipment, adapted to some other kind of work, perhaps, but presumably ill adapted to removing snow. The special labor force is also bound to be of decidedly casual quality, unless the work is organized as emergency work temporarily claiming the services of men regularly occupied otherwise.

The adjustment between supply and demand for meats and fruits by cold storage is an instance of an important contribution to the solution of a load-factor problem. Whether it has been employed merely in this way to perform a legitimate economic function, however, has been questioned. If any considerable amount of food has thus been carried over from one seasonal supply peak not merely up to but through another supply peak, the presumption is that the device has been used to withhold supplies from the market and as an instrument of commercial exploitation of the public rather than as a means to true economy. Moreover, when supply and demand peaks coincide, as, for example, in the case of turkeys, there is ground for increased suspicion of exploitation.

The agitation of the appeal to "do your Christmas shopping early" affords an interesting illustration of the possibility of reducing a peak demand by educating the consuming public. It lies within the power of consumers greatly to reduce the unevenness of demand and the burden of bad load factors and thus to promote more economical production. However, they can not be expected to do this without inducement. In fact, prices are to a considerable extent adjusted in such a way as to provide the inducement.

The question of price differentiation is one with which the load factor has much to do. It calls for mention here, however, only because of the reluctance of consumers to admit the justification for differentiation, due largely to their failure to appreciate the

[12] Extraordinary liabilities incurred by the street-cleaning department for the removal of snow and ice from Feb. 14 to Mar. 31 amounted to $1,726,000 for Manhattan Borough, as appears in the *Minutes of the Board of Estimate and Apportionment of the City of New York for 1914*, pp. 1242 and 2691.

load factor as an element in unit cost. This situation will tend to improve in proportion as the significance of load-factor considerations in matters of consumption comes to be more generally recognized.

VII. The three coördinate variation factors are conjointly applicable to any kind of productive enterprise.

The later writers of the English classical school went about as far towards a systematic and, by intention, comprehensive analysis of the variation of returns as could be expected before the development of a situation such as to call attention to the load factor. John Stuart Mill in a frequently quoted statement[13] refers to "That fundamental law of production from the soil . . . that increased labor, in any given state of agricultural skill, is attended with a less than proportional increase of product." And he further says, "No tendency of a like kind exists with respect to manufactured articles. . . . The larger the scale on which manufacturing operations are carried on, the more cheaply they can be performed. Mr. Senior has gone the length of enumerating as an inherent law of manufacturing industry, that in it increased production takes place at a smaller cost, while in agricultural industry increased production takes place at a greater cost."

Senior's discussion[14] is best summed up in these words: "Additional labor when employed in manufactures is *more*, when employed in agriculture is *less*, efficient in proportion."

These are fairly definite statements of the facts of both diminishing and increasing returns and they barely fall short of expressing these principles in terms of the variation of unit cost. However, they unfortunately associate each principle with a distinct branch of production and further suggest opposition between the proportionality factor and the density factor of a sort that will not bear examination. But even if the conception of diminishing returns is not adequate and that of increasing returns not correct, these are but the limitations of the viewpoint of the time and, in fact, of a much later period as well.[15] The principle of diminish-

[13] Bk. IV, ch. 2, par. 2, of the *Principles*.

[14] Pp. 81-86 of his *Political Economy*.

[15] Cf. Marshall, *Principles* (5th ed., p. 150): "An increase in the capital and labor applied in the cultivation of land causes *in general* a less than proportionate increase in the amount of produce raised, unless it happens to coincide with an improvement in the arts of agriculture." The "in general" is cautionary and refers to the situation before the point of diminishing returns has been

ing returns should be generalized and broadened until it relates to the proportions in which labor and instruments may be used in connection with land, not with land in general, but with a specific area or piece of land. It is perhaps necessary to add that the specified area may possibly be the entire surface of the earth. When attention shifts from land, as the productive agent of which the supply is least flexible, and therefore the one of which the amount available in general for a particular enterprise is most likely to be predetermined, to some other relatively invariable agent, it would seem better to call the principle in question by the more abstract name "proportionality factor." The principle of increasing returns made specific is that unit costs—fundamentally this should be cost measured in units that do not themselves vary like commercial or pecuniary expenses—decrease as the commercially practicable scale and density of productive operations increase.

Once the economic significance of the load factor is understood, it will be seen that this explanatory principle also is of general applicability. What the theory of rates for electrical supply thus offers to pure science is doubtless of less scope than the principle suggested to the minds of economists by agricultural conditions in England at the beginning of the nineteenth century. But, as explanatory principles, the proportionality factor, the density factor, and the load factor are of coördinate importance. Historical changes in comparative prices and modern differential price making can not be explained without making use of all three principles of the variation of productivity. These economico-technical principles are, by comparison with ordinary commercial factors in price determination, like the gravitational forces that control the level of the waters in comparison with the winds that make the waves.

The relations between the three principles may best be shown in their connection with each other by an illustration of their mode of operation in a single enterprise, for example, a street railway.

reached. The principle is made applicable to land only, and even there the essential idea of the limitation of area is either lacking or merely implied. On the other hand, Carver (*Distribution of Wealth,* 1904, p. 65) is clear and explicit in the sense of the writer. Bullock, in the article already cited, is also clear on this point. Commons, likewise (*Distribution of Wealth,* 1893, ch. 3, par. 1) attaches most importance to the limited-area conception of diminishing returns.

Such a corporation will usually own land for car houses, power stations, and substations, and an office building. If its car houses are in the suburbs, the cars will probably all be stored on the street level. On Manhattan Island this would be poor economy. Several floors will be used for cars, at the cost of elevating them and of more expensive building construction. Where and how the power station and office building will be constructed will be decided on the same principle. Of course, the degree of use of a site and its costliness react upon and condition each other, so that the point of equilibrium with regard to the proportion of capital invested on a given area depends upon density as well as proportionality.[16] Similarly, the intensity of the use made of the street may compel, and also make economically possible through density of traffic, a more expensive type of construction. Underground conduit construction, costing perhaps twice as much, is a substitute for the trolley electric line with its overhead obstructions. The roadway itself may be put above the street or below. Each step increasing the use of the public way is made at greater cost. But the economic demand is frequently great enough to pay for such intensive "cultivation," despite diminishing returns, that is, the obtaining of fewer feet of floor space for a given outlay in constructing and operating the building, or fewer miles of track per unit of investment.

Unless a railroad or street railway can obtain a certain amount of traffic—freight or passengers or both—per mile of road, it will not pay at all. As the density of traffic becomes greater the road becomes more and more profitable. Increasing traffic may compel the construction of an additional track and thus the increasing profitableness of the road will be irregular. But a double track road will efficiently transport more than twice as much traffic as a single-track road and it does not cost twice as much. Similarly, betterments of roadway yield more than they cost, provided, of course, traffic conditions warrant the outlay. An underground four-track road, the New York subway, accommodated 12,800 passenger car miles per day per mile of road between 42d Street and Brooklyn Bridge in 1912.[17] The

[16] Cost and value, it should be noted, here as always in discussing economico-technical principles, are to be conceived as physical or psychical rather than commercial quantities, though of course the commercial unit may be used as a makeshift unit and will ordinarily serve well enough.

[17] This is the number of car trips (round) over the track in question (that

average passenger car miles per mile of road for the surface railways, practically all double track, on Manhattan during the same period was about 1100 per day. On the elevated tracks of Brooklyn Bridge 7400 car miles per mile were operated on a typical day in 1910—doubtless somewhat above the average per year including Sundays. Passenger traffic corresponds to car mileage sufficiently for the purposes of this comparison, though differences in the size of cars and the length of the passenger trip are qualifications that require mention. Figures of freight ton-miles per mile of steam railroad would illustrate the same point. In New York City, and, indeed, generally for cities, it appears that street railway traffic increases at a rate proportioned to something like the square of population, or at least according to some exponent not much less than 2. Track mileage, on the other hand, appears to bear a constant ratio to population. The proportion is no mere hypothesis, though it would be pretentious to call it a law unless one blunts the word by qualifying it as an "empirical law" and also avoids any suggestion of mathematical exactness. Equipment doubtless increases somewhat faster than track mileage, but not as fast as traffic, because of the tendency to use larger cars, if for no other reason. On the whole, there is evidently for street railways a marked tendency to "increasing returns."

The load factor of a street railway tends to improve somewhat with increasing density of traffic. But the problem of rush hours by no means disposes of itself. For example, on a certain typical day in November, 1910, according to counts made by the Public Service Commission, out of 174,224 passengers crossing Brooklyn Bridge to Manhattan Borough in a 24-hour period, 80,618 passed during the 2-hour period from 7 to 9 a.m. Nearly one half the passengers crossed in one twelfth of the time. In the remaining 10 hours to 7 p. m. 65,432 persons crossed. For passengers from Manhattan to Brooklyn, corresponding figures were 81,275 for the 2-hour peak from 5 to 7 p.m., out of a 24-hour total of 168,685 and as compared with 54,389 in the preceding 10 hours. As indicative of the one-way character of the traffic at the peak time, the eastbound passengers from 7 to 9 a.m. numbered 6,281 and the westbound from 5 to 7 p.m., 10,250. The back-haul traffic against the rush was only 10 per

is, all the car trips of the subway) multiplied by 2. *Cf.* p. 261 of vol. II of the *Annual Report of the N. Y. Public Service Commission for the First District for 1912.*

cent of the traffic in the other direction. Figures of a somewhat different nature are shown by the ticket sales of the New York subway as distributed by hours. They do not take account of the direction of traffic and are for an extensive line instead of for a particular point which the traffic passes. To whatever extent heavy traffic in one direction is accompanied by scant traffic in the other direction the reflected variation is reduced. That the figures are for ticket sales instead of for rides taken is unessential. The total ticket sales for a day[18] were 1,060,202. The average per hour was thus 44,175. The hour of greatest density of traffic, from 8 to 9 a.m., shows 115,870, or 262 per cent of the average. On this basis one might figure a diurnal load factor of 38 per cent, provided one cared to assume that the northbound passengers' demand for accommodations is appeased by the knowledge that there are plenty of seats going south at some part of the line. The situation of the New York subway is probably more favorable than that of most street railways, both in the degree to which the traffic in one direction tends to balance that going in the opposite direction, and also in the comparative evenness in distribution of traffic through the day. The diurnal load factor for Brooklyn Bridge, according to the figures above referred to is:

$$\text{Eastbound } \frac{168685}{24 \times 49766} = 14.1 \text{ per cent}$$

$$\text{Westbound } \frac{174224}{24 \times 43628} = 16.6 \text{ per cent}$$

This sort of situation is the foundation of the problem of the strap-hanger. It should be recognized that it would be a very difficult operating and financial problem for a street railway to provide seats for all comers at rush hours. There is not only the regular daily variation and its irregular fluctuations to provide for, but the annual or seasonal variation is conspicuously great in the case of the New York subway and also for all surface lines serving amusement parks and summer resorts. It is evident that street railways generally fall far short of being able fully and continuously to utilize their plants.

All these principles of the variation of productivity are phases of the economic influence of the supply of complementary agents

[18] January 22, 1914. See p. 96 of vol. II of the *Annual Report of the New York Public Service Commission for the First District for 1913.*

where the respective supply (at a given price) of each, or its cost, can not be turned on and off at will, or is not adjustable by decrease or increase at will and without disturbing the balance of the factors of production, according to need or demand. To fail to see the way in which they interact with and supplement each other may involve misapprehending the significance of any one of them.

From this point of view, as completing the circle of the general factors entering into the variation of productivity and unit cost, the load-factor principle has theoretical and practical importance greater than its apparently restricted scope may suggest. But it is evident that, even on the basis of its place only in industries where its practical importance has been recognized in one way or another, it has a necessary place in any tolerably comprehensive view of the variation of productivity. The concept is applicable to every industry characterized by a heavy investment of fixed capital and by a product that has in some degree the nature of a service, that is, where circumstances restrict the time and place of consumption or enjoyment in a way to require contiguity to the producing agent. The concept is important also, though not dominant, in all branches of production affected by seasonal variation of demand. Even if we disregard all other applications of the principle and consider only the annual load factor, it is difficult to find any branch of production or service where the load factor has not some importance.

While a comprehensive statistical study of the three principles of variation of productivity could not fail to clear up much that is perplexing, it would probably also present to us another problem like the astronomer's "problem of three bodies." Where we can not control the interrelations of several complex variables nor postulate their independence of each other, our deciphering of their effects must be practical rather than scientific in the sense of "exact science." Economic society is a loose-jointed machine, or rather organism, the interrelations between the parts and appliances of which do not lend themselves to thoroughly mathematical treatment. Yet it is common in cost accounting not merely to assume that two of the variation factors can be treated as constant, while attention is directed to a third, but even to assume that there is no variation in productivity. For this reason it is wise to take a good many cost-accounting results

cum grano salis. The idea that a determinate unit cost can be fixed for any product or service is certainly subject to considerable qualification with reference to the fact that the result is itself a function of the variable degree of use made of appliances. Extent of use is not an unimpeachable basis of cost-apportionment, though it may be a practically useful makeshift. Neglect of this point may impair the soundness of railroad rate theory, which needs to take account of the density factor, and of electrical rate theory, which similarly needs to regard the load factor. The useful application of both these principles involves price differentiation. There is a causal connection between the variation of rates or prices per unit and the variation of costs, but the two are not necessarily parallel.

Whether or not the term "load factor" comes into general use in economics, the idea and the general principle are needed. Economists can learn much from engineers, especially since the engineers have taken to studying economics. The writer will be gratified if this paper contributes toward a greater interest in economic technology, as contrasted with the commercial and financial aspects of the science.

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